NIST Energy Savings Office Investigation

Presentation of Results

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Mark Davis

Energy Savings Office Project Partnership

Building and Fire Research Laboratory (BFRL)

- Responsibilities
  - Calorimeter construction and instrumentation
  - Data collection and analysis
  - Presentation of results
- Contributors
  - Hunter Fanney
  - Mark Davis
  - Luis Luyo
  - Michael Couch

Plant Division

- Responsibilities
  - Implementation of energy saving features
- Contributors
  - Jatin Patel
  - Daniel Mann

Typical Office Module

- Exterior walls
  - Zero insulation between metal panels and concrete structure
- Window unit
  - Single pane glass
  - Aluminum frame
  - No thermal break
  - Uninsulated aluminum panel below window unit
- Heating/Cooling
  - Forced air from attic
  - Induction coil unit

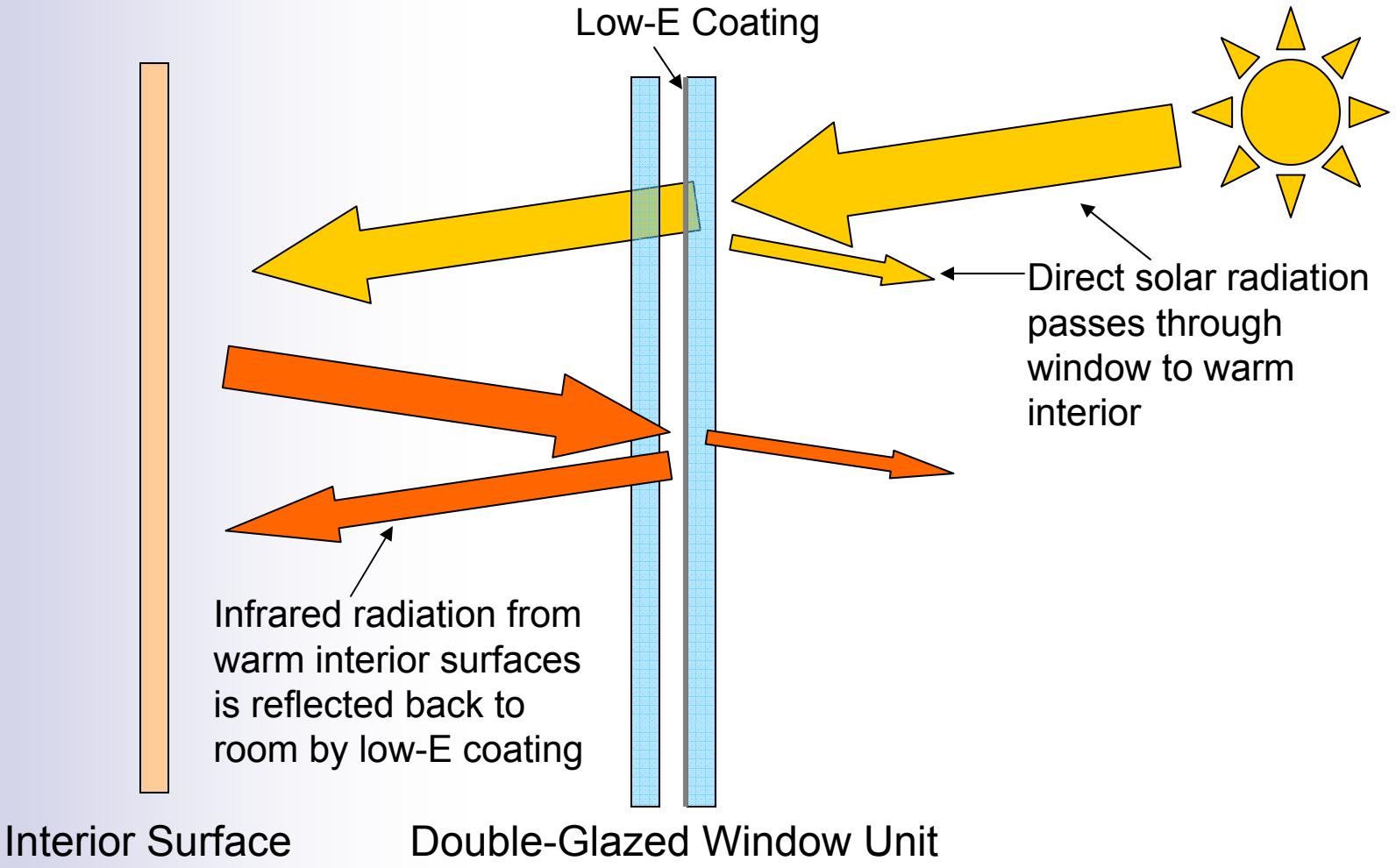
Modified Office Module

- Exterior walls
  - R-13 glass fiber insulation
  - Air leaks sealed
- Window unit
  - Installed insulated window unit
    - Double glazed
    - ½" air gap
  - Insulated panel below window
    - R-20 polystyrene board
    - R-13 fiberglass batt
- Heating/Cooling
  - Forced air register moved to top of window
  - Induction coil unit

Detailed Modification Photos

Detailed Insulation Work Completed by Group Technician

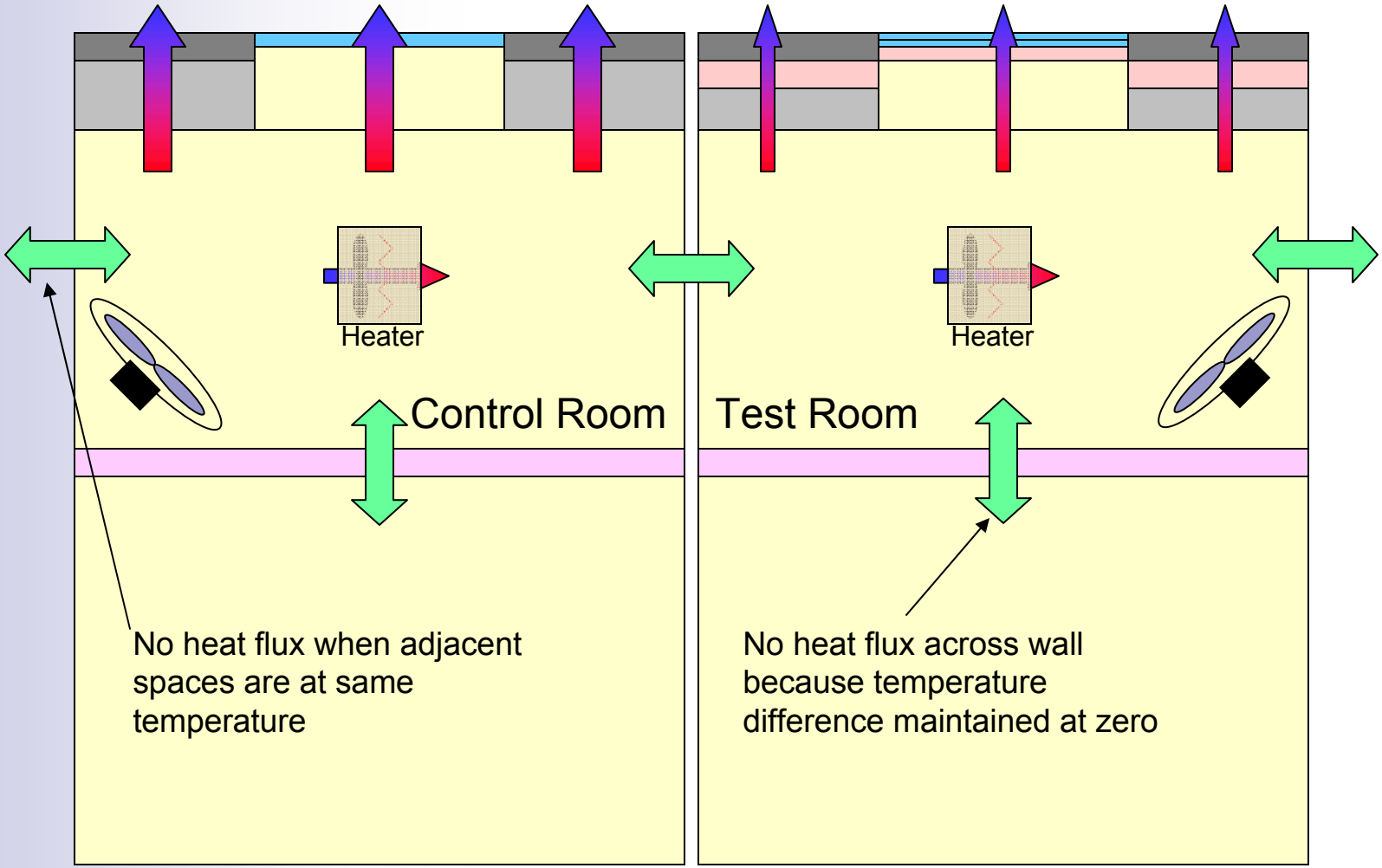
How a Low-E Coating Works



How Energy Savings Is Determined

- Two adjacent office modules
  - Control office
  - Test office with energy saving features
- Calorimetric method
  - Fabricated insulated partition wall in each room
  - Heated window-side space to maintain zero temperature difference across partition wall
  - Heat loss confined to exterior wall
  - Energy required to maintain each room at an equivalent temperature measured

Calorimetric Method



Instrumentation and Control

- Thermopile across insulated partition wall
  - Measures temperature difference across wall
  - Used to control heater on window-side of each room
    - PID controller turns heater ON/OFF until thermopile reads zero
- Power analyzers measure electrical energy added to each room
- Thermocouple grid measures air temperature throughout rooms
- Thermocouple measures outdoor temperature
- Calibrated heat flux transducer measures heat flux through window
  - Mounted in center of each window
  - Guarded area ensures one-dimensional heat transfer through window

Define Heat Transfer Coefficient (UA Factor)

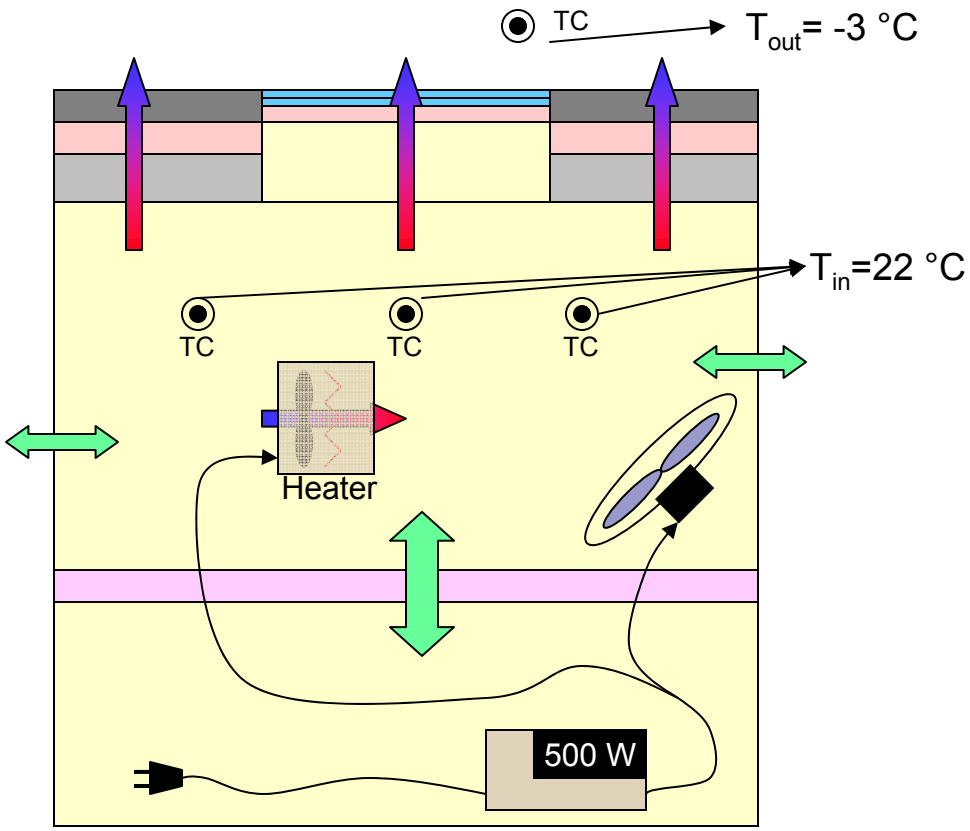
- UA factor expresses heat loss as a function of temperature difference across a surface

$$UA = \frac{\text{Heat lost through wall}}{(T_{in} - T_{out})}$$

- Assume that electrical energy input to room passes through exterior wall as heat

$$UA = \frac{500\ W}{22°C - (-3°C)} = 20\ W/°C$$

- **Smaller UA factor means better energy efficiency**



Presentation of Results

- Summarize results for
  - UA factor for exterior wall
    - R-13 insulation level
    - R-32 insulation level
  - Infrared thermography
  - Heat flux through window
- Explain discrepancy between measured and expected window performance

- Notes
  - Experiments do not include new air distribution vent at top of window and supplemental heat exchanger
  - Data is for an office on north side of building, and results for offices on south side may be different due to solar heat gain

Summary Result Table

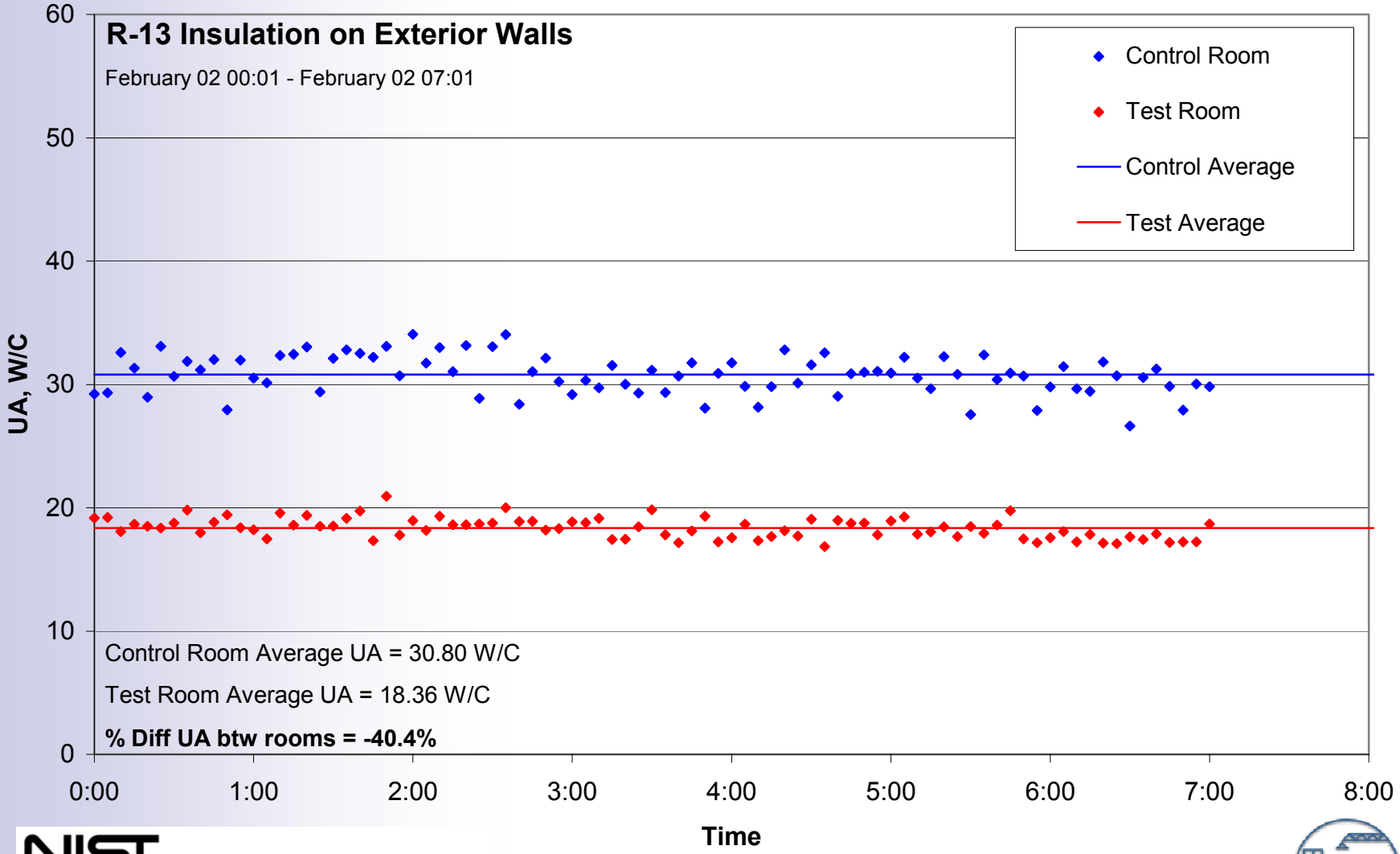
Double-Galze Air-Filled Window Unit with R-13 Insulation on Exterior Walls

Test Date	Test Period	Average Outdoor Temperature *°C*	Average Rooftop Windspeed *mph*	UA Factor - Whole Exterior Wall			Heat Flux Through Window		
				Control Room *W/°C*	Test Room *W/°C*	% Difference *%*	Control Room *W/m^2*	Test Room *W/m^2*	% Difference *%*
Jan 17	0:00 to 12:00	-4.36	8.50	32.0	20.7	-35.2%	158.1	88.8	-43.8%
Jan 20	0:00 to 24:00	-0.93	11.80	37.7	24.3	-35.5%	144.3	78.5	-45.6%
Jan 22	18:00 to 24:00	0.55	2.40	30.0	21.0	-29.8%	92.7	60.0	-35.2%
Jan 23	0:00 to 7:00	1.29	6.20	34.3	23.3	-32.2%	112.3	65.4	-41.8%
Jan 24	0:00 to 7:00	0.74	2.90	32.0	20.4	-36.3%	98.8	60.2	-39.0%
Jan 27	0:00 to 7:00	-3.79	3.50	36.3	21.8	-40.0%	127.0	77.4	-39.1%
Jan 29	0:00 to 7:00	-5.59	14.20	38.3	19.3	-49.5%	181.9	94.6	-48.0%
Jan 30	0:00 to 7:00	-4.85	3.00	34.0	21.6	-36.3%	129.8	81.5	-37.2%
Jan 31	0:00 to 5:30	-5.07	9.50	37.7	21.6	-42.6%	160.4	90.6	-43.5%
Feb 01	0:00 to 7:00	-1.49	4.90	33.8	20.5	-39.5%	111.0	68.1	-38.6%
Feb 02	0:00 to 7:00	-0.21	3.10	30.8	18.4	-40.4%	103.9	61.9	-40.4%
Feb 03	0:00 to 10:00	-3.39	7.00	34.0	19.6	-42.4%	145.8	81.0	-44.5%
Feb 04	0:00 to 10:00	-4.74	7.00	34.7	20.3	-41.6%	149.2	84.0	-43.7%
Feb 05	0:00 to 7:00	-9.44	9.20	37.4	21.6	-42.2%	180.1	101.3	-43.7%
Feb 06	0:00 to 7:00	-12.21	6.60	38.6	23.8	-38.3%	183.0	108.0	-41.0%
Feb 07	0:00 to 7:00	-8.05	5.60	36.2	22.9	-36.6%	139.9	87.3	-37.6%
Feb 08	0:00 to 7:00	-7.37	6.00	37.1	23.7	-36.2%	148.5	94.2	-36.6%
Average				**35.0**	**21.5**	**-39%**	**139.2**	**81.3**	**-42%**

Double-Galze Air-Filled Window Unit with R-32 Insulation on Exterior Walls

Feb 23	0:00 to 7:00	0.65	18.50	34.2	16.7	-51.0%	144.2	76.1	-47.3%
Feb 24	0:00 to 16:00	-2.32	8.60	32.3	17.7	-45.4%	127.8	70.2	-45.0%
Feb 25	0:00 to 24:00	0.55	2.80	28.2	15.0	-46.9%	96.3	55.3	-42.5%
Average				**31.5**	**16.4**	**-48%**	**122.8**	**67.2**	**-45%**

Feb 2nd – UA Factors for Whole Exterior Wall



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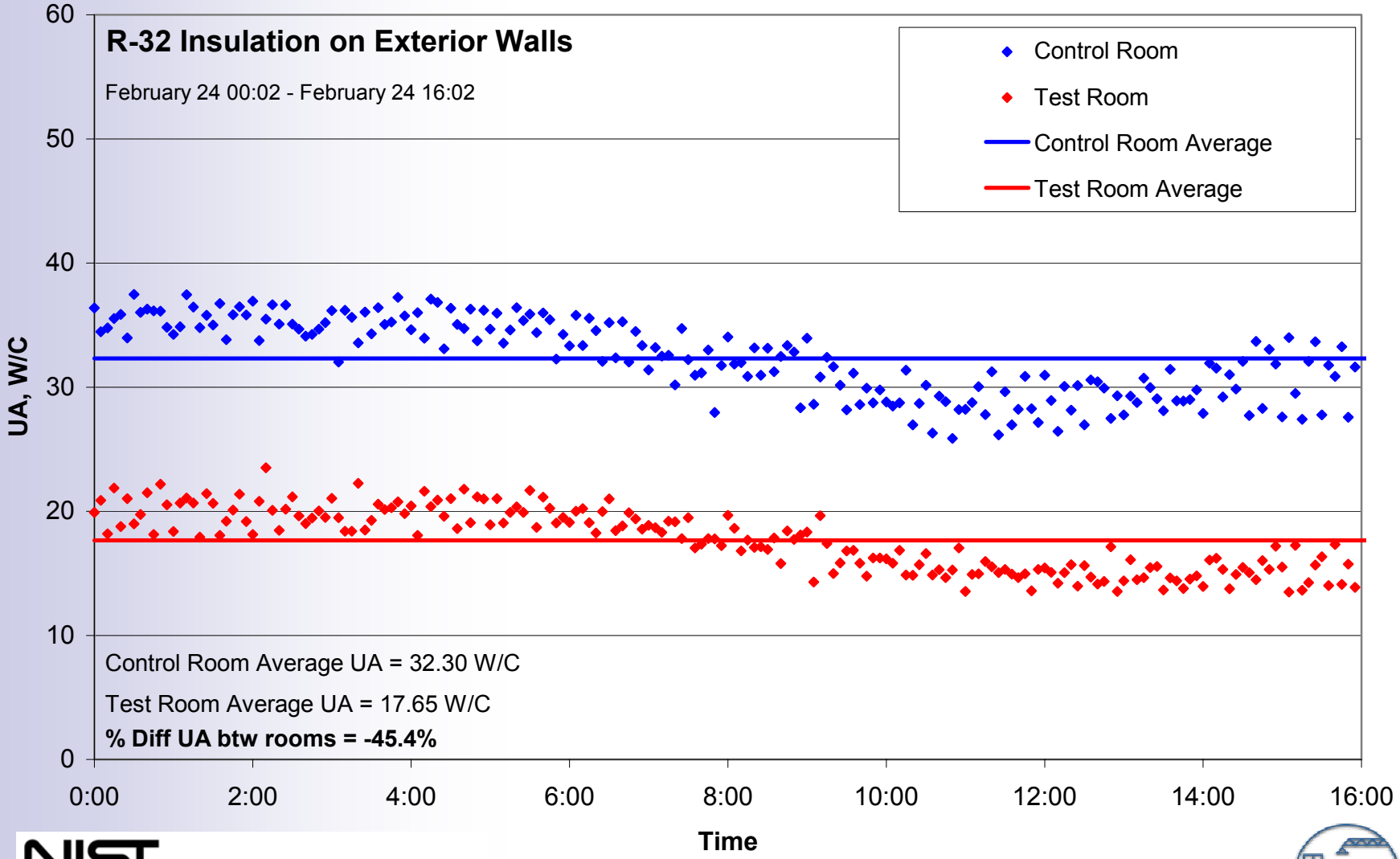
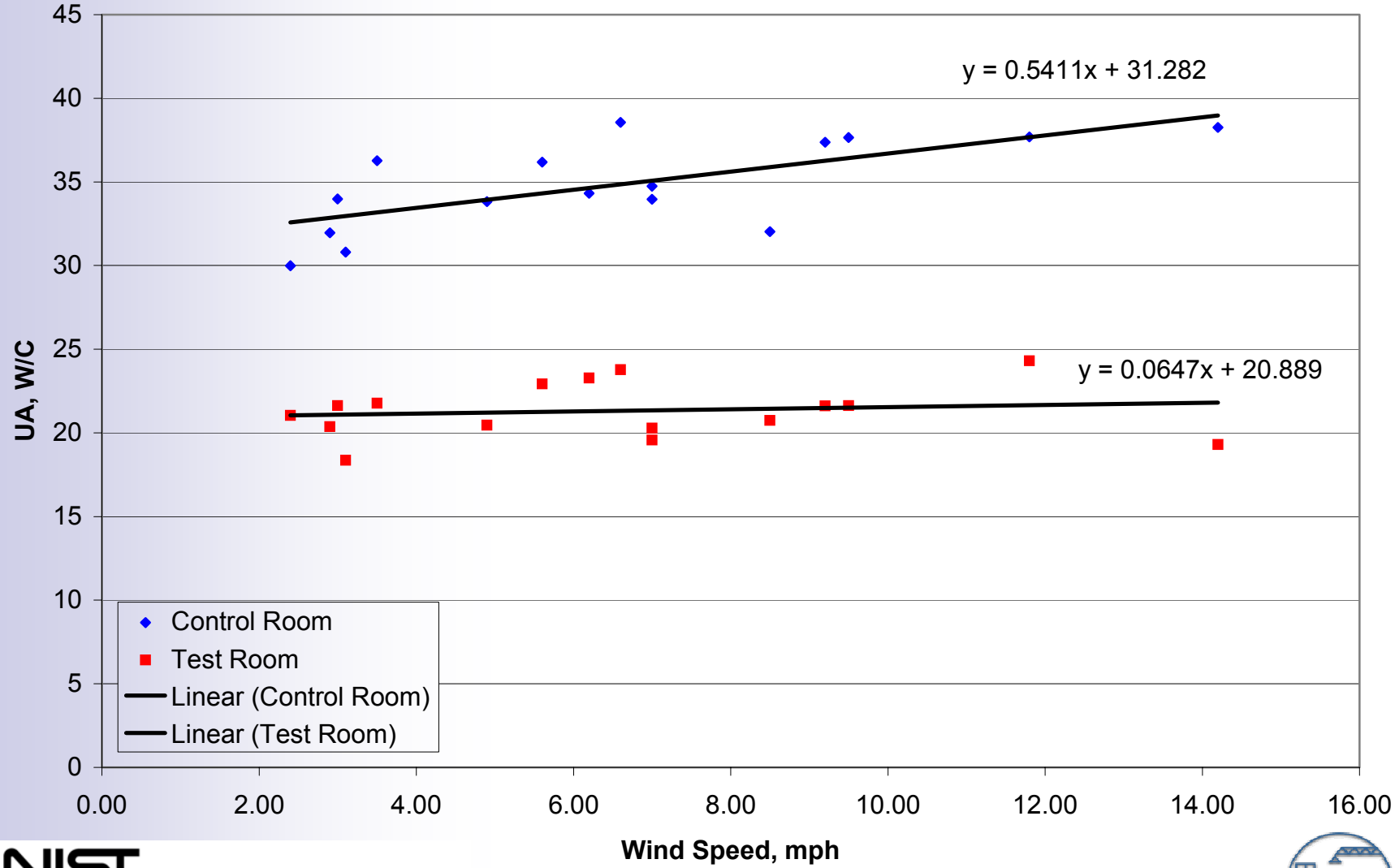
Feb 24th – UA Factors for Whole Exterior Wall



UA Factor for Whole Exterior Wall vs. Wind



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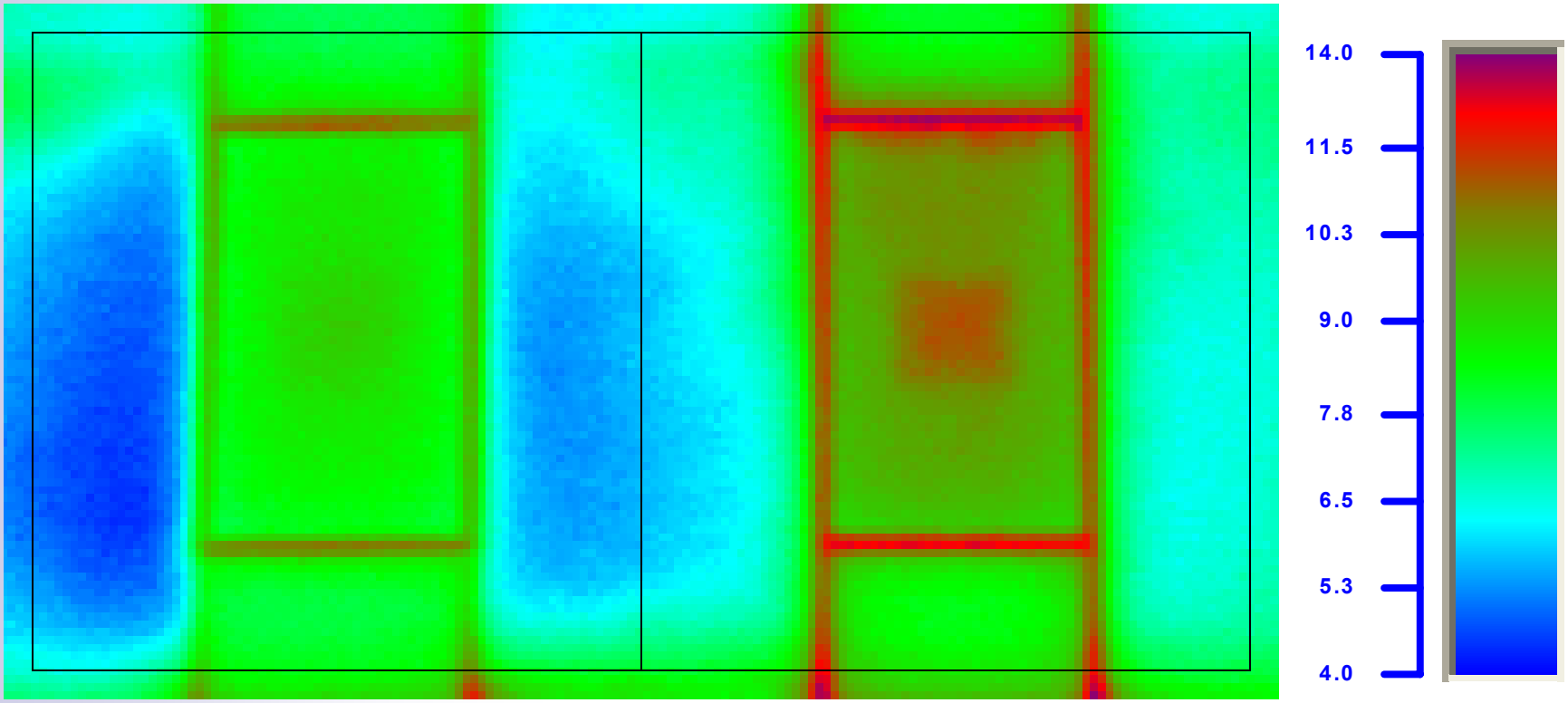
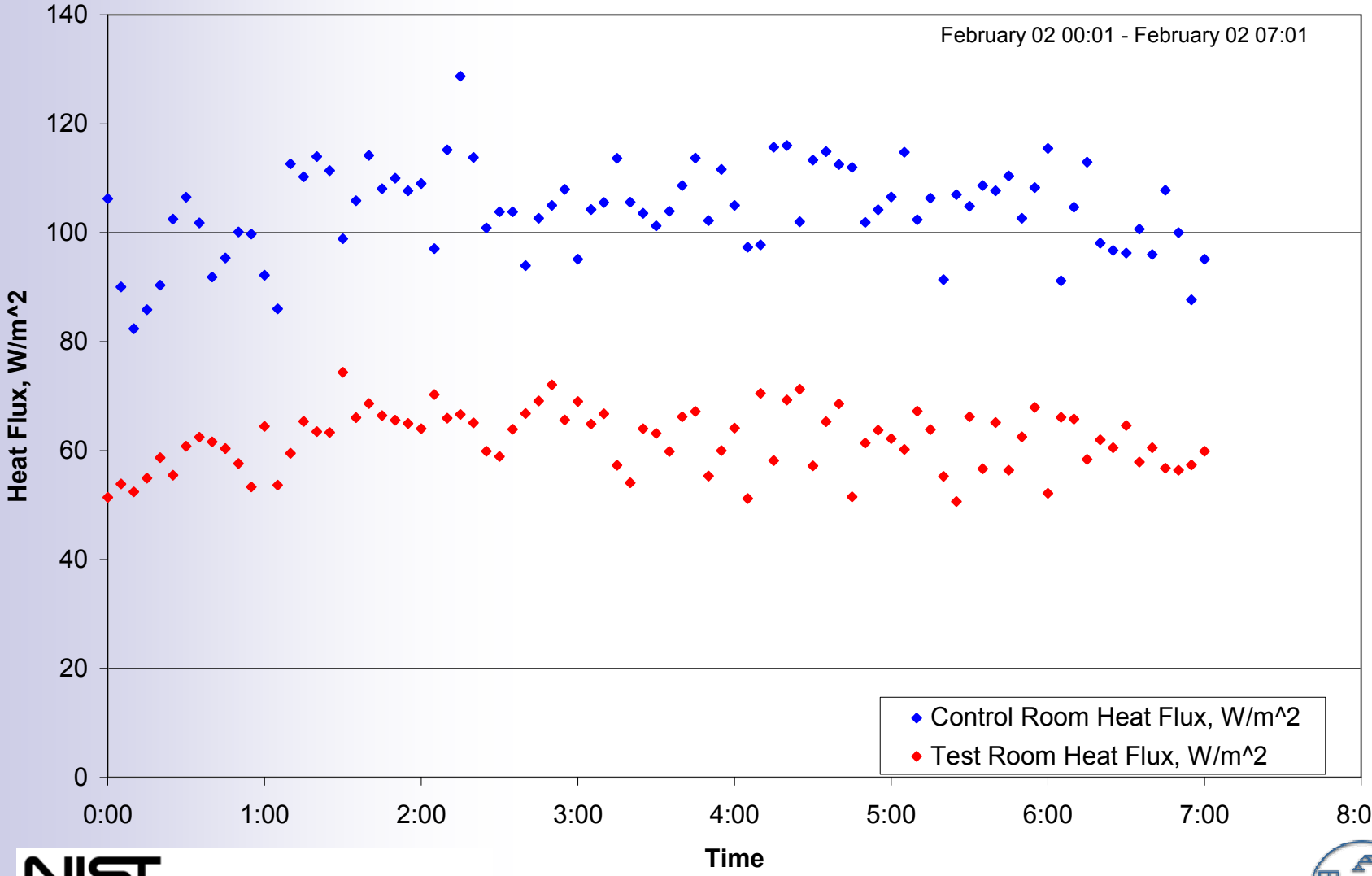
Infrared Image of Control and Test Room Exteriors



February 2nd – Window Heat Flux



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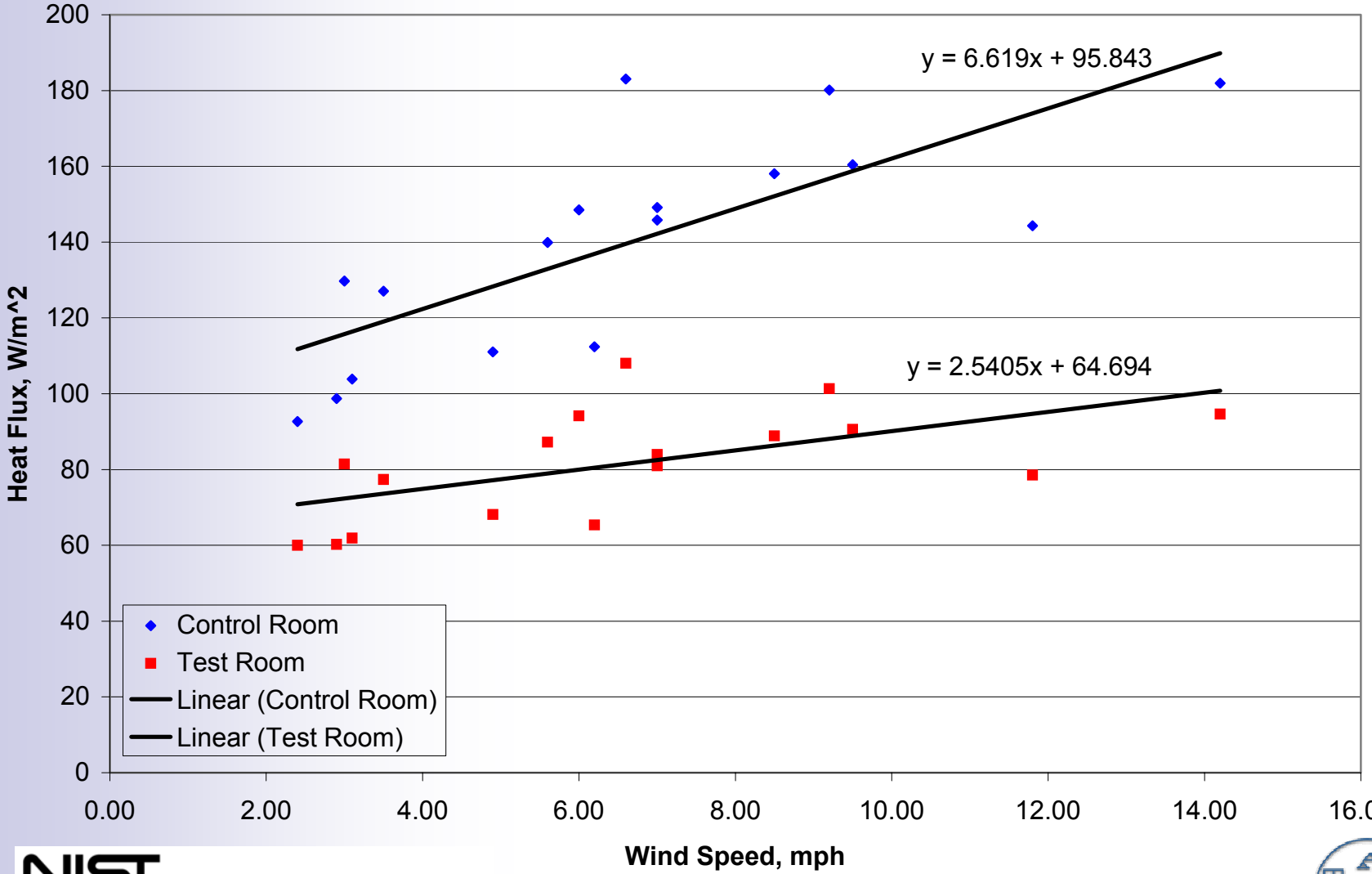
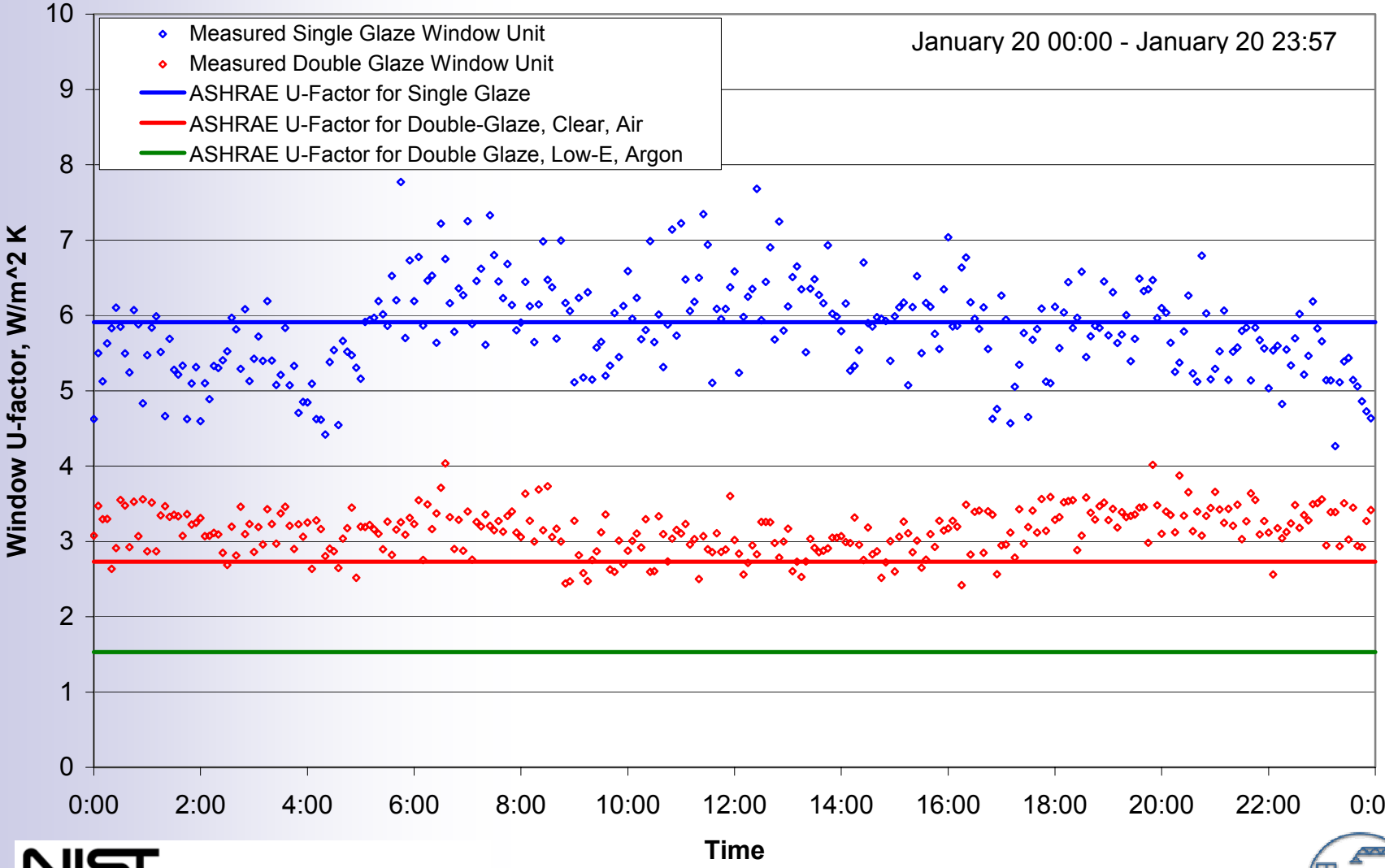
Heat Flux Through Window vs. Wind

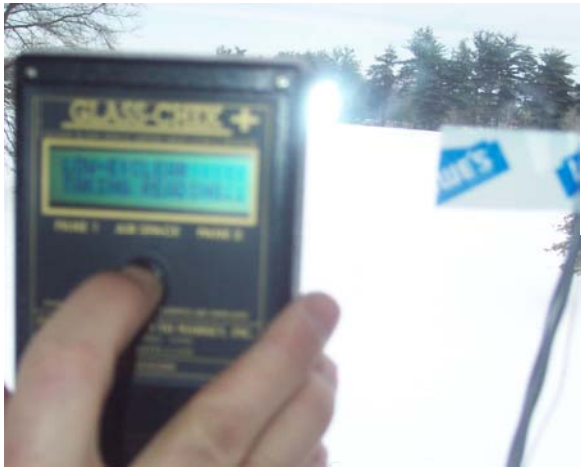


Window U Factors – Measured and Calculated



NFRC Representative Checks Window Unit

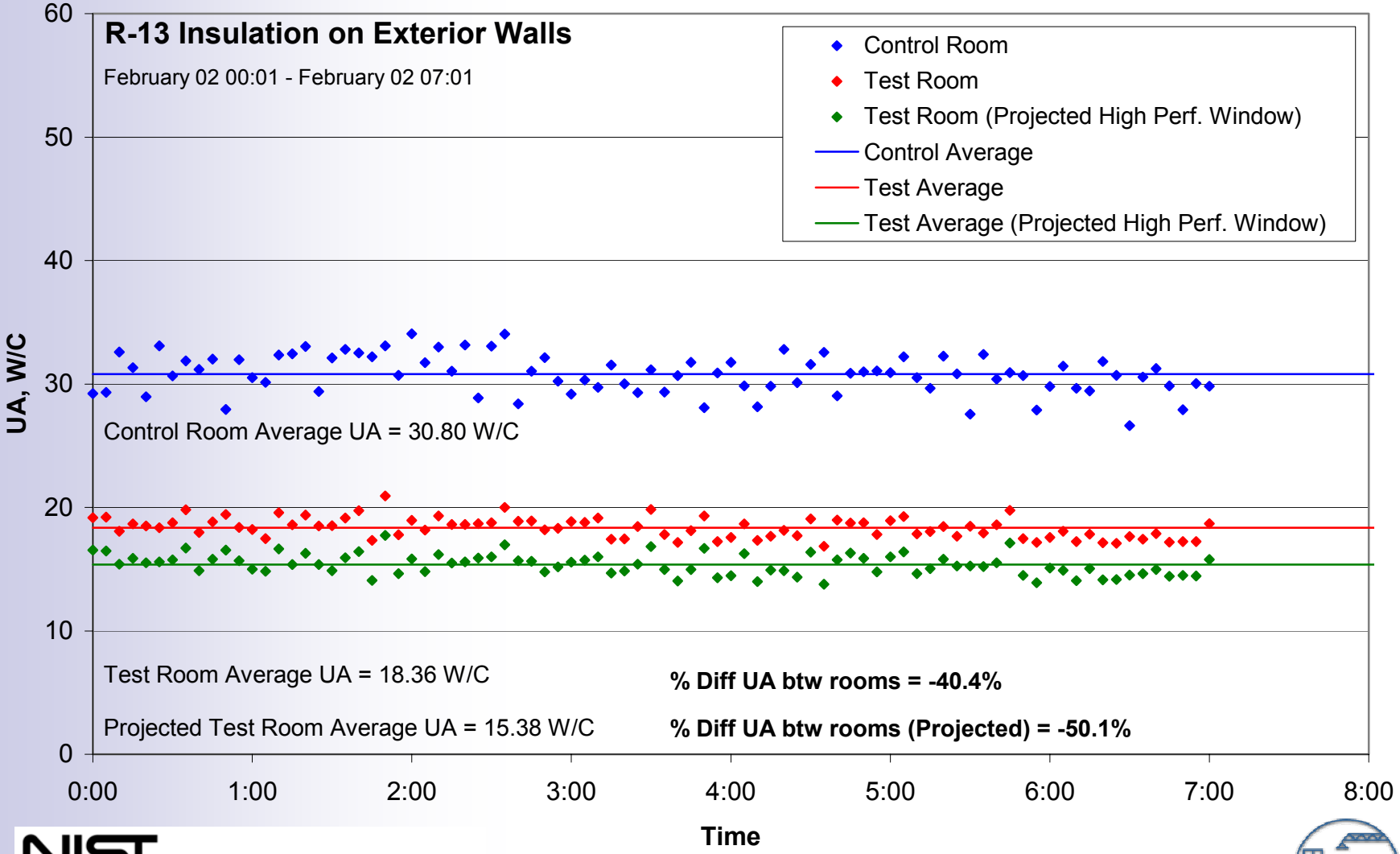
- National Fenestration Rating Council (NFRC) administers rating system for the energy performance of windows
- Technical Services Manager, Ray McGowan, visited NIST to test double-glazed window unit for presence of low-E coating
- Used handheld instrument shown
  - Check for presence of low-E coating
  - Measure glass thickness
  - Measure air gap
- **Confirmed window unit does not have low-E coating**



Measured Results Modified to Project Savings Using High Performance Window

- UA factors were adjusted using ASHRAE tabulated values to project performance of whole exterior wall using originally intended window unit
  - Double-glaze, ½" air space
    - ASHRAE Fundamentals U-factor = 2.56
  - Double-glaze, Low-E (ε=0.1), ½" argon space
    - ASHRAE Fundamentals U-factor = 1.53
- Measured heat loss through window subtracted from total
- Heat loss through theoretical window unit calculated
- Added to heat loss through metal walls to obtain projected total heat loss through whole exterior wall

Feb 2nd – UA Factors for Whole Exterior Wall



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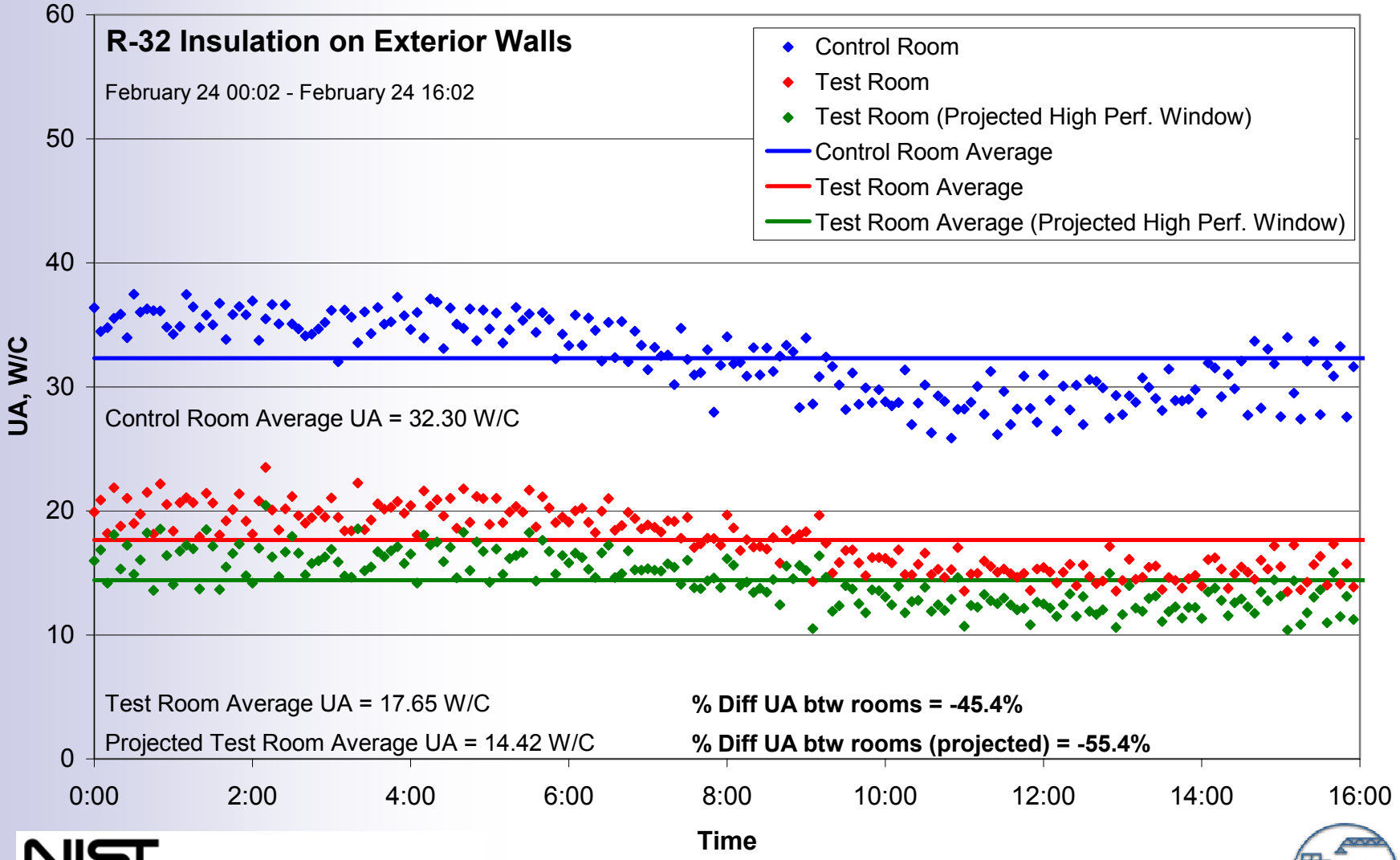

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Conclusions

- R-13 insulation on exterior wall plus double-glazed window unit decreased office energy usage by almost **40%**
- Adding an extra layer of R-19 insulation (for a total of R-32) decreased office energy use by **48%**
- Projections for double-glazed / low-E / Argon-filled window unit will decrease modified office energy usage to **>55%** of unmodified space
- Double-glazed window unit decreased window heat flux by 40%

Next Steps

- Collect additional data with R-32 wall insulation
- Install low-E / argon-filled window unit and collect data
- Compute energy savings at central plant
  - Account for conversion efficiency at central plant and distribution losses
- Plant Division to develop / obtain cost to modify offices with energy saving features
- Explore techniques to estimate annual savings